

*A Dual Task Paradigm*  
*The cerebral laterality of pitch and rhythm and*  
*implications for aphasia therapy*

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## Table of Contents

|      |  |    |
|------|--|----|
| I.   | Abstract.....  | 2  |
| II.  | Background .....   | 3  |
|      | A. Aphasia .....   | 3  |
|      | B. Melodic Intonation Therapy .....  | 3  |
|      | C. Aphasia Recovery.....   | 6  |
|      | D. Pitch and Rhythm Laterality.....  | 8  |
|      | i. Laterality of Pitch in Normal and Brain Damaged Subjects.....   | 8  |
|      | ii. Laterality of Rhythm in Normal and Brain Damaged Subjects....  | 9  |
|      | iii. Summary of Pitch-Rhythm Laterality Findings.....  | 11 |
|      | E. Dual Task Paradigm.....   | 12 |
|      | i. Theory of Dual Task Paradigm.....   | 12 |
|      | ii. Findings of Past Dual Task Paradigms .....   | 12 |
|      | iii. Research Question.....  | 13 |
| III. | Methodology.....   | 16 |
|      | A. Study Design.....   | 16 |
|      | B. Procedure.....  | 16 |
|      | i. Participant Recruitment.....  | 16 |
|      | ii. Inclusion Criteria Screening.....  | 16 |
|      | iii. Determining Tone Span.....  | 17 |
|      | iv. Experimental Conditions.....   | 18 |
|      | 1) Single Condition Verbal Reproduction Task.....  | 18 |
|      | 2) Single Condition Motor Task.....  | 18 |
|      | 3) Dual Condition Task.....  | 19 |
| IV.  | Data.....  | 19 |
|      | A. Data Collection and Analysis.....   | 19 |
| V.   | Discussion.....  | 26 |
|      | A. Did Dual Task Paradigm confirm or contradict the previous findings<br>regarding the laterality of rhythm and pitch in the brain?..... | 26 |
|      | B. Implications for Aphasia Therapy and Future Steps.....  | 29 |
| VI.  | Conclusion.....  | 32 |

## I. Abstract

Melodic Intonation Therapy (MIT), a melody-based method for treating aphasia, is presumed to activate the undamaged right cerebral hemisphere in the wake of stroke-induced damage to the language controlling regions of the left hemisphere. This right hemisphere activation pattern has occurred alongside significant language improvements in those with aphasia that are treated with MIT. Neuroimaging studies have shown, however, that the best long-term language outcomes occur when language function re-lateralizes to the left hemisphere. In turn, this suggests that it could be advantageous to understand how to differentially stimulate the right and left brain hemispheres for inducing cortical plasticity at different stages of language recovery. The goal of this project is to determine whether results of a dual task paradigm confirm or contradict previous findings regarding the laterality of pitch and rhythm in the brain. The relative degree of dual task detriment can be predicted by comparing the relative number of ‘activities’ being completed in each of the hemispheres for a given dual task pairing. These predictions based on literature review generated eight hypotheses regarding which conditions would show a greater dual task detriment. Results of this study do not confirm or negate the hypotheses, but do suggest some noteworthy trends. This includes performance enhancement in the majority of the dual task conditions, when it was presumed that there would be a performance detriment in all or most of the dual task conditions. This trend is attributed to a couple of possible factors. These include the presence of an “attentional boost” involved in the cognitive processing of the tasks, as well as the documented facilitative effect of “doodling” on recall of auditory information. These influences may override any discernible detriment in the dual task conditions, which suggests that the present dual task paradigm setup is unsuitable for exploring the cerebral organization of pitch and rhythm.

## II. Background

### A. Aphasia

For many who have suffered left hemisphere brain damage from stroke or traumatic brain injury, aphasia is a common problem. Aphasia is an impairment in the use of language for speaking, listening, reading and writing (Lingraphica, 2007). Non-fluent aphasia, in particular, results from damage to the areas of the left hemisphere responsible for language production. Non-fluent aphasia involves greatly reduced speech output, and contains mostly nouns and very elementary grammatical and syntactic structures (Rolandi, 2005). It has been observed for more than 100 years that though people with nonfluent aphasia cannot speak fluently, they can sing due to lack of lesions in the right brain hemisphere (Norton, Schlaug, Zipse, & Marchina, 2009).

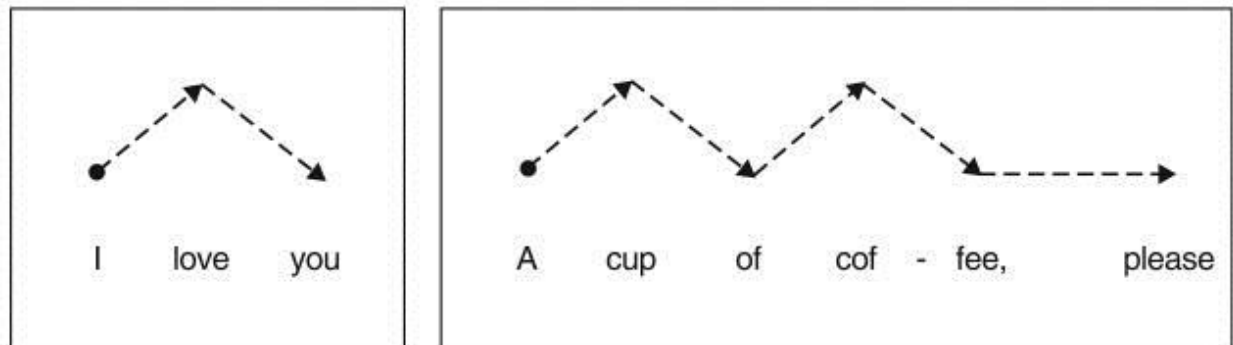
### B. Melodic Intonation Therapy

This phenomenon of intact singing ability in those with non-fluent aphasia was the premise for the development of Melodic Intonation Therapy (Schlaug, Marchina, & Norton, 2008). A therapy used with individuals with non-fluent aphasia, Melodic Intonation Therapy, or MIT, was developed with the aim of improving propositional speech and overall phrase length in these patients. This method begins by having the patient intone two to three syllable phrases using two pitches, and eventually increasing the phrase length to five syllables or more while fading out the intonation towards regular speech again (Norton et al, 2009).

This treatment occurs across three stages; Elementary, Intermediate, and Advanced. Each stage targets 20 words or social phrases (i.e. "I love you") that are considered highly probable for that particular patient to use in their daily life. The treatment takes place at a table or desk, with the speech-language pathologist sitting at one side and the patient sitting on the other side. The words or phrases are paired with visual cues when presented to the patient. For the Elementary

and Intermediate stages, these words or phrases are intoned with two contrasting pitches, one high and one low. The pitch variations assigned to each phrase correspond with the normal speech stress patterns. Stressed syllables are assigned the higher pitch, and unstressed syllables are assigned the lower pitch. The stress-based pitch assignments for the Elementary and Intermediate stages of MIT are illustrated in the following diagram:

**Figure 1.**



(Schlaug et al, 2008, p. 315)

In the advanced stage, the speech-pathologist presents longer and more syntactically complex phrases in a 'speaking' voice for the patient to repeat, in order to transition them from singing to functional speaking. For all three stages, the speech-language pathologist raises the patient's awareness of rhythm by tapping the patient's left hand on the table one time for every syllable (Helm-Estabrooks, 1989). Furthermore, the left hand movement is controlled by parts of the motor area in the right cerebral hemisphere that are close to the parts of motor area used for movement of the speech articulators. In turn, it is hypothesized that the left hand movement also may assist the process of motor movement for speech (G. Ramsberger, interview, October 16 2012).

A patient is an appropriate candidate for MIT if they satisfy the following criteria; 1) stroke etiology (not traumatic brain injury or other kind of neurological injury), 2) has an isolated lesion

or lesions confined to the frontal temporal region of the left hemisphere, 3) displays the qualities of non-fluent aphasia, 4) relatively good auditory comprehension, 5) poor verbal repetition abilities, 6) poor articulatory agility, 7) good emotional stability, 8) preserved memory skills, 9) motivation and 10) attention to detail (Helm-Estabrooks, 1989). For those who satisfy the criteria for candidacy for MIT, it can be a particularly effective method of speech-language treatment when compared to a control therapy featuring non-intoned repetitions. This comparison was made by Schlaug and colleagues in their 2010 study on the efficacy of MIT (Schlaug, Norton, Marchina, Zipse, & Wan, 2010). It was found that those who received MIT showed a 200 percent greater propositional speech output than those who received the non-intoned control therapy (Schlaug et al., 2010). This was measured by counting the number of correct information units (CIUs), or correct words that the patients produced. In another study on the efficacy of MIT, it was found that non-fluent aphasic patients treated with MIT (compared to those treated with a non-intoned repetition therapy comparable to the aforementioned one devised by Schlaug and colleagues), showed significantly greater word repetition abilities after being treated with six weeks of intensive therapy (five hours per week). Also, those treated with MIT showed significantly higher scores on the ANELT test (Amsterdam-Nijmegen Test for Everyday Language) than their counterparts in the study who received the non-intoned control therapy (van de Sandt-Koenderman, van der Meulen, Heijenbrok-Kal, Visch-Brink, Ribbers, 2013). The average ANELT score of MIT-treated patients was 6.6 points, as opposed to 2.3 points for the patients receiving the control therapy. This indicates that not only did their repetition scores increase, but that the MIT-treated patients experienced an improvement in everyday functional language ability (van de Sandt-Koenderman et al., 2013).

MIT was developed based on the notion that the undamaged right hemisphere, implicated in the processing of music (Perani et al., 2010), can be encouraged to take on a greater role in language processing if features of language production are made more similar to music (Helm-Estabrooks, 1989). MIT's relative effectiveness in encouraging communicative recovery is due not only to the recruitment of the non-damaged right hemisphere through singing, but also the left hand-tapping which likely activates the speech motor strip in the brain in the contralateral right hemisphere ( Schlaug et al., 2008). Speech produced in the initial stages of MIT is distinct from traditional speech in that it exaggerates the natural pitch fluctuations of speech, and it slows down the rate of speech (Helm-Estabrooks, 1989). Research done by Zatorre and Belin (2001) indicates that auditory information involving pitch variations is processed most heavily in the right hemisphere, and changes in rhythm information are processed more heavily in the left auditory cortex. According to this information provided by their research, the dramatic pitch fluctuations in MIT would cause the right hemisphere to be activated more so than the left hemisphere. Schlaug et al. (2010) also confirmed in their fMRI imaging scans that there is greater right hemisphere activation than left hemisphere activation for language tasks in patients after being treated with MIT.

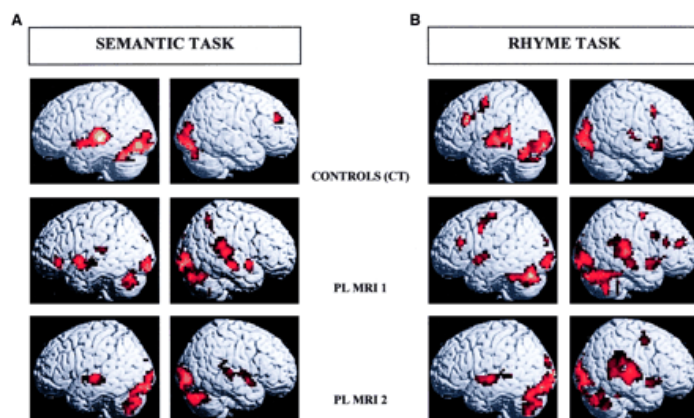
### C. Aphasia Recovery

The predominant lateralization of language to the left hemisphere in most neurotypical individuals has been well documented. When someone suffers a stroke that incurs damage to the left hemisphere, a treatment method such as MIT may encourage the compensatory activation of the undamaged right hemisphere to facilitate more functional language use. A medical study done by Fernandez and fellow researchers (2004) illustrates the natural progression of aphasia recovery in a 44 year-old male patient, PL, with mild conduction aphasia caused by lesions in the

Wernicke's area. The researchers compared this patient's hemispheric activation patterns to activation patterns in a group of normal (non-brain damaged) individuals. All individuals in this comparison were given semantic category identification and rhyming tasks. At the MRI scan one month after PL's stroke, he exhibited many phonemic mistakes in the rhyming task presented. He showed significant improvement on this rhyming task at the time of the second scan (twelve months after the stroke). For both the one month- and twelve month-post imaging scans, he performed comparably to the neurologically normal control subjects in respect to the semantic category task. This illustrates preserved semantic access in spite of his stroke. In the imaging scans one month after PL's stroke, his brain showed a predominant lateralization of language tasks to the right parietotemporal region, with weak activation in the perilesional areas of the left hemisphere anterior temporal cortex. This suggests an initial reorganization of lost language function to the right hemisphere (Fernandez et al., 2004). Twelve months after his stroke, his MRI scan shows relatively increased contribution of the left hemisphere perilesional areas to language activities. Temporal regions remained strongly activated, with increased activation of the perilesional areas of the left hemisphere. In both the one month and twelve months scans, occipitotemporal and cerebellar regions

were activated bilaterally. PL's improvement in phonemic rhyming tasks concurrent with the re-lateralization of language regions from the right hemisphere to the left perilesional areas (see Figure 2)

**Figure 2. MRI Scans at 1 & 12 Months Comparing PL to Controls on Two Tasks.**



suggests that optimal language outcomes rely on reactivation of the left hemisphere to regain



control of language functions. This suggests that speech-language therapy for patients with aphasia should emphasize tasks that encourage language function to re-lateralize to the left hemisphere. In turn, this suggests it would be therapeutically advantageous to understand how to differentially stimulate the right and left hemispheres.

Other studies have illustrated the predominant involvement of the lesioned left hemisphere for facilitating language recovery in those with aphasia. Researchers Heiss and Thiel (2006) illustrated how activation of the left hemisphere perilesional neural substrate is the primary mechanism by which aphasia recovery occurs. As part of an H<sub>2</sub><sup>15</sup>O-PET study, they administered a word repetition task to patients with various aphasia types and lesion locations, at two weeks- and eight weeks-post stroke. Particularly in those patients with lesions that mostly spared the language-controlling temporal regions of the left hemisphere, the researchers observed better recovery from language deficits when these perilesional regions of the left hemisphere could be reactivated. In these cases there was some observed right hemisphere contribution to language function, but only when the left hemisphere language substrate was irretrievably damaged.

#### D. Pitch and Rhythm Laterality

##### i. Laterality of Pitch in Normal and Brain Damaged Subjects

Perani and colleagues (2010) performed a study on neurotypical infants to determine if there is an innate neurobiological right hemisphere lateralization for the processing of pitch. They found that when newborns listen to melodic stimuli, there is strong right hemisphere dominance for pitch processing, which is in line with findings on the laterality of pitch processing in adult brains as well. In imaging studies on the laterality of pitch and rhythm processing, Zatorre & Belin (2001) found that while rhythm appeared to be processed most

significantly in the left auditory cortex of his subjects, the pitch variations of the presented stimuli served to activate the right auditory cortex to a greater extent than the left. These results, in turn, suggest a tendency for pitch information to be processed in the right cerebral hemisphere. They propose this hemispheric asymmetry for pitch processing is due to anatomical differences between the brain hemispheres in regard to myelination and spacing of the cortical columns (Zatorre & Belin, 2001).

In a clinical study of a patient with a right hemisphere stroke, pre- and post-incident singing samples of this individual were compared (Murayama, Kashiwagi, Kashiwagi, & Mimura, 2004). Analysis indicated that while the rhythmic structures and overall melodic contour were preserved in the post-stroke recordings, the intervals between the different pitches were inaccurate. This indicates there was impacted pitch awareness in the presence of right hemisphere damage; this also suggests that the capacity for pitch perception and production are lateralized to the right hemisphere.

#### ii. Laterality of Rhythm in Normal and Brain Damaged Subjects

Research conducted on the laterality of rhythm suggests that the hemispheric location of rhythm depends upon the type of rhythm being dealt with (such as metric or nonmetric). One particular study examining the hemispheric laterality of rhythm coordination in speech production was done by Riecker and colleagues (Riecker, Wildgruber, Dogil, Grodd, & Ackermann, 2002). The study utilized fMRI to investigate rhythm production in speech abilities in neurologically normal individuals. After presenting the subjects with a baseline task of passive listening to nonsense syllables that were metric, or isochronous (of equal duration), they were prompted to verbally produce both isochronous and nonmetric syllable patterns. Nonmetric

patterns were described as having varying syllable durations. The study results indicated that the nonmetric patterns were processed most heavily in the right anterior secondary auditory cortex. Given the right hemisphere-dominant neural representation of nonmetric patterns, it is likely that the right hemisphere contributes to the reproduction of nonmetric syllable sequences. In contrast, the production of metric (same duration) syllable patterns is lateralized to the left hemisphere (Riecker et al., 2002)

Another study done by Horvath et al. (2011) further looked at the issue of laterality of rhythm in the brain, specifically where non-metrical rhythm is processed. Freely spoken sentences were classified as nonmetric, as the syllables do not follow a steady, repeating pattern. Therefore, Horvath and fellow researchers designed a study in which they transformed these nonmetric sentences into Morse-code sequences and monitored via fMRI how eleven right-handed, female, native Hungarian speakers processed these non-metrical sequences through passive perception. They found that there were activations in the right hemisphere, specifically in the superior temporal and the posterior inferior frontal regions. In the left hemisphere, they also found some activation in the superior temporal region. They concluded that the processing of sentence-like, nonmetric sequences is mostly restricted to the right hemisphere. They attribute this to a right hemisphere-lateralized, frontal-temporal network that coordinates the processing of the continuously altering rhythmic structure of the nonmetric sentences or patterns (Horvath et al., 2011).

### iii. Summary of Pitch-Rhythm Laterality Findings

Review of various literature sources indicate that pitch and rhythm, though both elements of melody, are likely supported by two different neural substrates in separate hemispheres. In summary, the processing of pitch appears to be lateralized to the right hemisphere (Murayama et al., 2004; Perani et al., 2010; Zatorre & Belin, 2001), while the laterality of rhythm appears to be dependent on the type of rhythm; metric rhythm seems to be processed in the left hemisphere (Riecker et al., 2002) and nonmetric rhythm in the right hemisphere (Horvath et al., 2011).

As was described earlier, MIT serves to activate the undamaged right hemisphere to encourage compensatory language function after stroke-induced left hemisphere damage. Given the research-backed supposition that language function recovers best when it re-lateralizes to the left hemisphere (Fernandez, et al., 2004; Heiss & Thiel, 2006), it could be therapeutically valuable to better understand which features of melody are processed in the right and left hemispheres, respectively. With this knowledge, a refined version of MIT could be developed that intentionally activates the right hemisphere in the acute stages of aphasia recovery and then the left hemisphere in chronic stages to induce cortical reorganization of language function to the left hemisphere. Alternatively, activation of the right hemisphere could be avoided completely by emphasizing only strong rhythmic stimuli to activate the left hemisphere.

Given the information provided by the literature reviewed, this thesis project will utilize a dual task paradigm to discern the cerebral laterality of pitch and rhythm. Ultimately, the knowledge gained from this experiment may be beneficial in refining existing aphasia therapies, such as MIT, to make them more effective for treating aphasia.

## E. Dual Task Paradigm

### i. Theory of Dual Task Paradigm

The dual task paradigm is a research method in cognitive neuroscience used to learn more about cognitive processes and whether two different processes share cognitive resources. In this method, participants complete two activities under different conditions. The activities are first performed individually and features of performance are documented. Then the two tasks are performed simultaneously and performance features are again documented. If the two activities are utilizing similar cognitive processes with common neural bases, the dual task detriment will be larger than if the two activities are utilizing different sets of cognitive processes and neural substrates (Baddeley, Della Sala, Papagno, & Spinnler, 2006).

### ii. Findings of Past Dual Task Paradigms

Past dual task paradigm studies have looked at the effect of dual task activities on task performance in those with Alzheimer's disease compared to control subjects who were young adults and elderly individuals without any neurologic disease. The subjects were all given a box-checking activity with a digit span task, separately (for the single tasks) and simultaneously (for the dual tasks). On the dual task the two adult control groups (elderly and young) did not show any detriment when completing the tasks simultaneously. However, those with Alzheimer's disease showed significant detriment in their performance on the dual task condition (Baddeley, Baddeley, Bucks & Wilcock, 2001). A study by Huntsinger & Jose (1991) presented twenty-eight musically experienced and twenty-eight musically inexperienced children (ages six-ten) with various digit and tone sequences to replicate. In both groups, within each subject production of digit sequences was significantly more accurate (and therefore easier to remember) than were the tone spans. Random tone span patterns were particularly difficult for all the subjects to

reproduce, and a significant production deficit was recorded for reproduction of the tonal sequences. Given the relative difficulty of tone sequence reproduction to digit sequence reproduction, it could be expected that there would be greater difficulty in completing a box-checking and tone sequence recall dual task pairing than a box-checking and digit span recall pairing as in the 2001 Baddeley study. Therefore, there could plausibly be a dual task detriment in neurologically normal adults when presented with the simultaneous tone sequence reproduction task and box-checking task.

Fearing and fellow researchers performed a dual task study on twelve right-handed males and twelve left-handed males to determine if a simultaneous verbal task yielded different effects in finger- and foot-tapping speeds for the two groups (Fearing, Browning & Corey, 2001). When given the “single task” of finger- or foot-tapping on their right and left sides, the right-handed individuals showed a faster tapping rate for their right side than their left side. When presented with a verbal task to complete while tapping either their finger or foot on the right or left side, the right- and left-handed participants showed a significant detriment in their right side finger-tapping rate and a facilitative effect in the left-side tapping rate. Contrastingly, with the concurrent verbal task and foot-tapping tasks there was a bilateral detriment in foot-tapping rates for both right- and left-handers. Given that detriments are expected with two tasks that share common neural substrate, it is in line with research that a dual task pairing with two left hemisphere-controlled tasks such as language and right hand function would result in a significant performance detriment.

### iii. Research Question

In this study, a unimodal motor task will be performed by the left and right hands with a task requiring repetition of syllables that vary in either rhythmic and/or pitch patterns. Since the

hand is controlled by the contralateral cerebral hemisphere and the portion of the motor strip controlling the hand movement is in close proximity to that which controls speech sound production, it is expected that there will be a difference in dual task detriment that will reflect either competition or no competition for common neural substrate (G. Ramsberger, interview, January 12, 2013). For example, according to the literature supported hypotheses of this study, metric rhythms are likely processed in the left hemisphere, nonmetric rhythms in the right, pitch changes in the right hemisphere, and no pitch change sequences in the left hemisphere. If, in a dual task condition, a participant is presented a ‘metric rhythm and no pitch change’ sequence (in which the metric rhythm is presumed to be mediated by the left hemisphere, and the “no pitch change” element would be mediated in the left hemisphere instead of the right hemisphere), and if they completed the motor task with their right hand (controlled by the contralateral left hemisphere), there would be three “activities” being processed in the left hemisphere of the brain. In contrast, if they completed the same sequence type and did the motor task with their left hand (controlled by the contralateral right hemisphere), it would involve two “activities” being processed in the left hemisphere of the brain and one in the right hemisphere. In turn, it would be expected for there to be a greater dual task detriment (or degradation of task performance) for the sequence paired with the right hand motor task than for the same sequence paired with the left hand motor task. If this is empirically confirmed through the results of this study, then this would confirm the findings of Riecker and colleagues (2002) that metric rhythms are processed in the left hemisphere of the brain.

The research question for this study is whether results of a dual task paradigm confirm or contradict previous findings regarding the laterality of rhythm and pitch in the brain. The relative degree of dual task detriment can be predicted by comparing the relative number of ‘activities’

being completed in each of the hemispheres for a given dual task pairing. Thus, the following are the predictions for the relative dual task detriment for the dual task conditions:

1. The dual task detriment for Right Hand Motor Task+Metric Rhythm+No Pitch Change (Condition 9) is expected to be GREATER than for the Right Hand Motor Task+Metric Rhythm+ Random Pitch Change (Condition 11)
2. The dual task detriment for the Right Hand Motor Task+Metric Rhythm + Random Pitch Change (Condition 11) is expected to show NO DIFFERENCE from Right Hand Motor Task+Nonmetric Rhythm+ Random Pitch Change (Condition 14).
3. The dual task detriment for the Left Hand Motor Task+Metric Rhythm+ Random Pitch Change (Condition 17) is expected to show NO DIFFERENCE from Left Hand Motor Task+Metric Rhythm+No Pitch Change (Condition 15).
4. The dual task detriment for the Left Hand Motor Task+Nonmetric Rhythm+Random Pitch Change (Condition 20) is expected to be GREATER than for the Left Hand Motor Task+Metric Rhythm+Random Pitch Change (Condition 17).
5. The dual task detriment for the Right Hand Motor Task+Nonmetric Rhythm+Random Pitch Change (Condition 14) is expected to show NO DIFFERENCE from Right Hand Motor Task + Nonmetric Rhythm+No Pitch Change (Condition 12).
6. The dual task detriment for the Left Hand Motor Task+Nonmetric Rhythm+Random Pitch Change (Condition 14) is expected to be GREATER than for the Left Hand Motor Condition+Nonmetric Rhythm+No Pitch Change (Condition 18).
7. The dual task detriment for the Right Hand Motor Task+Metric Rhythm+No Pitch Change (Condition 9) is expected to be GREATER than for the Right Hand Motor Task+Nonmetric Rhythm+No Pitch Change (Condition 12).



8. The dual task detriment for the Left Hand Motor Task+Metric Rhythm+No Pitch Change (Condition 15) is expected to show NO DIFFERENCE from the Left Hand Motor Task+Nonmetric Rhythm+No Pitch Change (Condition 18).

## II. Methodology

### A. Study Design

This is a single group study in which within-participant data were collected across 20 conditions (see App. B). The variable of interest is the dual task detriment for each tonal sequence type. Dual task detriment for each participant was determined by comparing a participant's performance when two tasks (verbal and motor) were carried out individually in the single task condition, with performance for the same two tasks when carried out simultaneously in a dual task condition. It was presumed that larger dual task detriments are the result of greater competition for shared cognitive resources.

### B. Procedure

#### i. Participant Recruitment

Participant recruitment began after Institutional Review Board approval was obtained for this study. Recruitment was conducted by posting flyers around campus, posting announcements on the CU Buff Bulletin, and asking SLHS professors to share information from the recruitment flier in their classes. Potential participants were asked to contact the aphasia lab through email, and they provided their name and a phone number by which they could be contacted (see Appendix A).

#### ii. Inclusion Criterion Screening

The potential participants were screened via a telephone interview and in-person screening to determine if they met the following inclusion criteria.

- 1) 18 years of age or older (telephone)
- 2) No history of neurologic injury, disease, learning disability, or speech, language or hearing impairment (telephone)
- 3) Right handed (telephone)
- 4) Non-musician as determined by our research-backed cutoff criterion (telephone)
- 5) Monolingual American English speaker (telephone)
- 6) Full use of upper extremities, or hands and arms (telephone)
- 7) Ability to discriminate between pitches (in person)
- 8) 20 dB HL or better hearing thresholds from 250-8000 Hz (in person)
- 9) Possess tone span of between 4 and 8 tones for five out of six condition types (in person).

iii. Determining Tone Span

Tone span was determined for each of the six condition types of pitch and rhythm sequences (See App. B). Participants heard a tone sequence and were asked to reproduce it using the syllable “vut.” Three sequences of each tone span were presented. If all three were reproduced correctly, then the tone span was increased by one tone. This continued until maximum span was reached as indicated by the longest span for which all three sequences were correctly reproduced. Tone span was determined for each condition for four different speeds: 60 tones per minute, 120 tones per minute, 180 tones per minute, and 240 tones per minute. The speed at which each participant could produce their optimum tone span for each condition was the speed at which the sequences for that condition were presented to them during the experimental procedures. Tone sequences were created using Noteflight notation software and were presented to participants via free field speakers in a soundproof booth, at a controlled

volume of 73 dB. If they were determined to be eligible, consent for study participation was obtained before beginning the experimental procedures in the following sessions.

iv. Experimental Conditions

Participants completed a total of twenty single and dual task conditions. The order of these twenty different conditions was randomized and delivered across two sessions to control for possible order effects. The first ten randomized conditions were presented to the participants during the first session, and the remaining ten conditions were presented during the second session.

1) Single Condition Verbal Reproduction Task

For the verbal reproduction task, the participant reproduced tone sequences, at the length equal to that individual's maximum tone span, for each of the six single verbal task conditions (Conditions 1-6). Sequences were presented one at a time, for a two-minute period. Performance on the verbal reproduction task was audio recorded for later analysis in which both the total number of sequences produced and the number of correct sequences produced were determined.

2) Single Condition Motor Task

Participants completed a pen and paper motor task with their right hand (Condition 7) that required them to make an "X" in as many checkboxes as possible on the given checkbox sheet. The participants were instructed to make each "X" so that the lines reached the corners of each box, but so the lines did not go beyond it. The same procedure then was repeated with the left hand (Condition 8). The participant's performance on the motor task was evaluated based on the number of checkboxes completed in a two-minute period.

### 3) Dual Condition Task

Participants performed a Motor Task simultaneously with a Verbal Reproduction Task for a two-minute period. This was repeated a total of twelve times: right hand + six condition types (Conditions 9-14), and left hand + six condition types (Conditions 15-20). Performances were audio recorded for later analysis of the verbal reproduction component as described above for the Single Condition Verbal task. Motor task performance was evaluated as described above for the Single Condition Motor task.

## III. Data

### A. Data Collection and Analysis

Data were collected for nine participants, and analyzed for five. These five participants were included because their data were fully collected and analyzed at the point when the thesis needed to be completed.

Table 1. Participant Characteristics

|              | P1               | P2    | P3    | P5    | P8    |
|--------------|------------------|-------|-------|-------|-------|
| Gender       | F                | F     | F     | F     | M     |
|              | Tone Span/Speed* |       |       |       |       |
| Conditions   |                  |       |       |       |       |
| c1, c9, c15  | 8/240            | 8/240 | 8/240 | 8/240 | 8/120 |
| c3, c11, c17 | 4/240            | 4/60  | 4/240 | 5/180 | 4/120 |
| c4, c12, c18 | 8/240            | 7/240 | 7/60  | 6/180 | 7/120 |
| c6, c14, c20 | 4/120            | 4/120 | 4/120 | 4/180 | 4/60  |

\*tones per minute

Of the twenty conditions only fourteen conditions of interest were analyzed for this thesis. While ‘predictable pitch change’ sequences were presented to the participants, for this analysis only the performances for ‘no pitch change’ and ‘random pitch change’ sequences were analyzed because it was hypothesized that the laterality of processing for “no pitch change” and “random pitch change” would be most different; thus increasing the likelihood that a dual task

detriment could be observed. Verbal reproductions were analyzed using Praat software to determine: 1) if the direction of pitch changes matched that of the model, and 2) if the number of tones reproduced matched that of the model.

Table 2. Raw Data of Five Participants for whom Analysis was Completed

|                        | P1    |        | P2   |      | P3   |      | P5   |      | P8   |      |
|------------------------|-------|--------|------|------|------|------|------|------|------|------|
|                        | Hand* | Tone** | Hand | Tone | Hand | Tone | Hand | Tone | Hand | Tone |
| Single Task Conditions |       |        |      |      |      |      |      |      |      |      |
| c1                     | Na    | 9      | Na   | 12   | na   | 15   | na   | 24   | na   | 9    |
| c3                     | Na    | 4      | Na   | 4    | na   | 17   | na   | 7    | na   | 8    |
| c4                     | Na    | 9      | Na   | 10   | na   | 3    | na   | 15   | na   | 10   |
| c6                     | Na    | 11     | Na   | 24   | na   | 12   | na   | 20   | na   | 1    |
| c7                     | 139   | na     | 146  | Na   | 85   | na   | 85   | na   | 151  | Na   |
| c8                     | 68    | na     | 71   | Na   | 51   | na   | 79   | na   | 141  | Na   |
| Dual Task Conditions   |       |        |      |      |      |      |      |      |      |      |
| c9                     | 88    | 17     | 116  | 17   | 76   | 13   | 150  | 18   | 212  | 13   |
| c11                    | 141   | 12     | 113  | 9    | 113  | 15   | 127  | 7    | 127  | 14   |
| c12                    | 105   | 12     | 128  | 13   | 73   | 5    | 175  | 12   | 155  | 10   |
| c14                    | 110   | 16     | 124  | 19   | 70   | 11   | 155  | 17   | 150  | 6    |
| c15                    | 66    | 10     | 58   | 14   | 48   | 15   | 76   | 13   | 86   | 12   |
| c17                    | 59    | 17     | 47   | 12   | 36   | 6    | 110  | 8    | 90   | 9    |
| c18                    | 66    | 6      | 61   | 14   | 29   | 2    | 87   | 14   | 65   | 7    |
| c20                    | 62    | 15     | 63   | 20   | 49   | 12   | 112  | 11   | 96   | 9    |

\*number of boxes completed; \*\*number of tone sequences completed correctly

Dual task detriment scores for each participant were determined by comparing single task condition performances for the motor checkbox task and the verbal tone reproduction task to corresponding dual task performances. Dual task detriment scores shown in Table 3 reflect raw score changes from the comparable single task condition as well as the net change (hand task + tone task) for each condition.

Table 3. Dual Task Raw Detriment Scores of Five Participants for whom Analysis was Completed

| P1   | Dual Task Conditions |     |     |     |     |     |     |     |
|------|----------------------|-----|-----|-----|-----|-----|-----|-----|
|      | c9                   | c11 | c12 | c14 | c15 | c17 | c18 | c20 |
| Hand | -51                  | 2   | -34 | -29 | -2  | -9  | -2  | -6  |

|    |      |     |     |     |     |     |     |     |     |
|----|------|-----|-----|-----|-----|-----|-----|-----|-----|
|    | Tone | 8   | 8   | 3   | 5   | -7  | 13  | -3  | 4   |
|    | Net  | -43 | 10  | -31 | -24 | -9  | 4   | -5  | -2  |
| P2 | hand | -30 | -33 | -18 | -22 | -13 | -24 | -10 | -8  |
|    | tone | 5   | 5   | 3   | -5  | 2   | 9   | 4   | -4  |
|    | net  | -25 | -28 | -15 | -27 | -11 | -15 | -6  | -12 |
| P3 | hand | -9  | 28  | -12 | -15 | -3  | -15 | -22 | -2  |
|    | tone | -2  | -2  | 2   | -1  | 2   | -11 | -1  | 0   |
|    | net  | -11 | 26  | -10 | -16 | -1  | -26 | -23 | -2  |
| P5 | hand | 65  | 42  | 90  | 70  | -3  | 31  | 8   | 33  |
|    | tone | -6  | 0   | -3  | -3  | -11 | 1   | -1  | -9  |
|    | net  | 59  | 42  | 87  | 67  | -14 | 32  | 7   | 24  |
| P8 | hand | 61  | -24 | 4   | -1  | -55 | -51 | -76 | -45 |
|    | tone | 4   | 6   | 0   | 5   | 3   | 1   | -3  | 8   |
|    | net  | 65  | -18 | 4   | 4   | -52 | -50 | -79 | -37 |

Four different analyses were conducted for this data. These were: 1) performance net change analysis, 2 & 3) performance detriment analysis (with both liberal and conservative parameters for establishing data significance), and 4) condition presentation order analysis.

Performance Net Change Analysis. When conducting the performance net change analysis and the performance detriment analysis, comparisons were tested based on whether the performance scores for the two conditions being compared were in line with the hypothesis for that pairing. A “difference” was counted if the scores for the conditions were more than one standard deviation of that participant’s data set from each other. The conditions were deemed “no difference” if the two scores were within one standard deviation from each other. Below, the data for the performance net change analysis is conducted to test the eight hypotheses presented in section E. iii (Research Question). This involves determining a performance percentage for the single verbal and motor tasks as well as the dual tasks within a condition type. The dual task score was based on a combining of the performance percentages on the verbal and motor tasks to

determine two net change percentage scores for that subject's performance (compared to the baseline single task performances).

Table 4. Performance Net Change Analysis

| Hypothesis<br># Tested | P1    | P2    | P3    | P5    | P8    | # of<br>YES's |
|------------------------|-------|-------|-------|-------|-------|---------------|
| 1                      | yes   | yes   | no    | no    | no    | (2/5)         |
| 2                      | no    | no    | yes   | yes   | no    | (2/5)         |
| 3                      | no    | no    | no    | no    | yes   | (1/5)         |
| 4                      | yes   | yes   | no    | yes   | no    | (3/5)         |
| 5                      | yes   | yes   | no    | yes   | no    | (3/5)         |
| 6                      | no    | no    | no    | no    | no    | (0/5)         |
| 7                      | no    | no    | yes   | no    | no    | (1/5)         |
| 8                      | yes   | yes   | no    | no    | yes   | (3/5)         |
| # of YES's             | (4/8) | (4/8) | (2/8) | (3/8) | (2/8) |               |

Note: Each "Yes" indicates a positive confirmation of a hypothesis; the fraction indicates the number of hypotheses confirmed out of the total tested.

While some hypotheses were determined to be correct, from the standpoint of within-subject analysis there were never more than 50% of the hypotheses that were correct. The highest hypothesis confirmation score was seen for Participants 1 and 2, with a confirmation score of 4/8 for both. However, from the group data perspective, there were three hypotheses comparisons which had a relatively high range of prediction accuracy, at 60% accuracy (3/5 confirmation rate). These were Hypothesis 4, Hypothesis 5, and Hypothesis 8. Across the group, Hypothesis 4 shows 3/5 confirmations of the hypothesis, Hypothesis 5 shows 3/5 confirmations, and Hypothesis 8 shows 3/5 confirmations. The remaining 5 hypotheses ranged in prediction accuracy of 0%-40% confirmations. Even with the most accurate hypotheses (Hypotheses 4, 5, and 8), the prediction accuracy for these are only 60% which reflects only a moderate majority. Also, the small number of participant data sets makes it difficult say with certainty that Hypotheses 4, 5, and 8 are true. These results did not yield strong trends for confirming or refuting the hypotheses. As the objective of the experiment is to measure any detriment present

in the dual task conditions, the performance detriment analysis was conducted next.

Performance Detriment Analysis. Performance detriment analysis involved testing the eight presented hypotheses (from section E. iii. Research Question) using only the detriment scores in each condition. If a particular dual task condition showed a detriment from the single task baselines, the detriment score would be used for the calculation; if a condition showed no percentage changes or only an enhancement from the single task baselines, a 0% would be used to represent that condition in the calculation. For the “conservative” difference criteria, a difference of ten between the detriment scores in the two compared conditions would constitute a significant difference. For the “liberal” difference criteria, a difference of five between the detriment scores in the two compared conditions would constitute a significant difference.

Table 5. Performance Detriment Analysis

| Hypothesis #<br>Tested | P1<br>Diff>10 | P1<br>Diff>5 | P2<br>Diff>10 | P2<br>Diff>5 | P3<br>Diff>10 | P3<br>Diff>5 | P5<br>Diff>10 | P5<br>Diff>5 | P8<br>Diff>10 | P8<br>Diff>5 | # YES's<br>from<br>either<br>analysis |
|------------------------|---------------|--------------|---------------|--------------|---------------|--------------|---------------|--------------|---------------|--------------|---------------------------------------|
| 1                      | yes           | yes          | no            | no           | yes           | yes          | yes           | Yes          | no            | no           | 3                                     |
| 2                      | no            | no           | no            | no           | no            | no           | no            | No           | no            | no           | 0                                     |
| 3                      | no            | no           | no            | no           | no            | no           | no            | No           | yes           | yes          | 1                                     |
| 4                      | no            | no           | no            | no           | no            | no           | yes           | Yes          | no            | no           | 1                                     |
| 5                      | yes           | yes          | no            | no           | no            | no           | yes           | No           | yes           | yes          | 3                                     |
| 6                      | no            | no           | yes           | yes          | no            | no           | no            | Yes          | no            | no           | 2                                     |
| 7                      | yes           | yes          | no            | yes          | yes           | yes          | no            | Yes          | no            | no           | 4                                     |
| 8                      | no            | no           | yes           | yes          | no            | no           | no            | No           | no            | no           | 1                                     |
| # of YES's             | (3/8)         | (3/8)        | (2/8)         | (3/8)        | (2/8)         | (2/8)        | (3/8)         | (4/8)        | (2/8)         | (2/8)        |                                       |

Condition Presentation Order Analysis. Given the occurrence of both performance enhancement and performance detriment in the dual task conditions in the data, further analysis was conducted regarding the possible influence of condition presentation order on performance net change and performance detriment. The random condition presentation order assigned to



each subject, along with their net change and detriment performance for each applicable dual task condition, is displayed in Table 6:

Table 6.

| Net Change in Performance (NCP) and Detriment in Performance (DP) for Conditions in Order of Presentation (CPO) |        |       |         |        |       |         |        |       |         |        |       |         |        |       |
|---|--------|-------|---------|--------|-------|---------|--------|-------|---------|--------|-------|---------|--------|-------|
| CPO TS 1  | P1 NCP | P1 DP | CPO TS1 | P2 NCP | P2 DP | CPO TS1 | P3 NCP | P3 DP | CPO TS1 | P5 NCP | P5 DP | CPO TS1 | P8 NCP | P8 DP |
| 9   | 52%    | -37%  | 10      | NA     | NA    | 18      | -77%   | -77%  | 11      | 49%    | 0%    | 1       | 100%   | ST    |
| 8   | 100%   | ST    | 17      | 166%   | -34%  | 1       | 100%   | ST    | 14      | 67%    | -15%  | 9       | 84%    | 0%    |
| 18  | -36%   | -36%  | 2       | NA     | NA    | 12      | 52%    | -14%  | 8       | 100%   | ST    | 8       | 100%   | ST    |
| 4   | 100%   | ST    | 16      | NA     | NA    | 15      | -6%    | -6%   | 19      | NA     | NA    | 5       | NA     | NA    |
| 1   | 100%   | ST    | 15      | -1%    | -18%  | 6       | 100%   | ST    | 20      | -3%    | -45%  | 4       | 100%   | ST    |
| 20  | 27%    | -9%   | 3       | 100%   | ST    | 7       | 100%   | ST    | 5       | NA     | NA    | *18     | -84%   | -84%  |
| 14  | 24%    | -21%  | 18      | 26%    | -14%  | 9       | -25%   | -25%  | 3       | 100%   | ST    | *13     | NA     | NA    |
| 7   | 100%   | ST    | 1       | 100%   | ST    | 17      | -94%   | -94%  | 6       | 100%   | ST    | *15     | -6%    | -39%  |
| 6   | 100%   | ST    | 11      | 102%   | -23%  | 4       | 100%   | ST    | 13      | NA     | NA    | *19     | NA     | NA    |
| 15  | 8%     | -3%   | 8       | 100%   | ST    | 19      | NA     | NA    | 17      | 53%    | 53%   | *7      | 100%   | ST    |

| CPO TS 2 | P1 NCP | P1 DP | CPO TS2 | P2 NCP | P2 DP | CPO TS2 | P3 NCP | P3 DP | CPO TS2 | P5 NCP | P5 DP | CPO TS2 | P8 NCP | P8 DP |
|----------|--------|-------|---------|--------|-------|---------|--------|-------|---------|--------|-------|---------|--------|-------|
| 17       | 312%   | -13%  | 6       | 100%   | ST    | 14      | -26%   | -26%  | 18      | 3%     | -7%   | 3       | 100%   | ST    |
| 2        | NA     | NA    | 5       | NA     | NA    | 2       | NA     | NA    | 10      | NA     | NA    | 17      | -23%   | -36%  |
| 12       | 9%     | -24%  | 9       | 20%    | -21%  | 8       | 100%   | ST    | 12      | 86%    | -20%  | 10      | NA     | NA    |
| 3        | 100%   | ST    | 14      | -36%   | -36%  | 10      | NA     | NA    | 2       | NA     | NA    | 14      | 499%   | -1%   |
| 5        | NA     | NA    | 13      | NA     | NA    | 5       | NA     | NA    | 15      | -50%   | -50%  | 12      | 3%     | 0%    |
| 16       | NA     | NA    | 20      | -28%   | -28%  | 3       | 100%   | ST    | 9       | 51%    | -21%  | 6       | 100%   | ST    |
| 10       | NA     | NA    | 19      | NA     | NA    | 16      | NA     | NA    | 4       | 100%   | ST    | 11      | 59%    | -16%  |
| 19       | NA     | NA    | 12      | 18%    | -12%  | 13      | NA     | NA    | 1       | 100%   | ST    | 16      | NA     | NA    |
| 11       | 201%   | 0%    | 4       | 100%   | ST    | 20      | -4%    | -4%   | 16      | NA     | NA    | 20      | 768%   | -32%  |
| 13       | NA     | NA    | 7       | 100%   | ST    | 11      | 21%    | -12%  | 7       | 100%   | ST    | 2       | NA     | NA    |

Note: NA=Not Analyzed; ST=Single Task, Comparison not Applicable

\*Conditions presented in Testing Session 2 due to time constraints in Testing Session 1

There is not a strong data trend for order effect and subject outcome

Summary of Findings. The data from the preceding analyses are not conclusive enough to confirm or refute the experiment hypotheses. However, some notable trends occurred in the data which might be worth analysis. Though dual task detriment was hypothesized to occur in all

the dual task conditions, dual task enhancement was much more prevalent than dual task detriment. “Significant” dual task performance enhancements are determined as any positive net performance percentage change (from the baseline single task) that is higher than one standard deviation for that respective data set. This was seen in 2 conditions for Subject 1 (Condition 11, Condition 17), 2 conditions for Subject 2 (Condition 11, Condition 17), 1 condition for Subject 3 (Condition 12), 5 conditions for Subject 5 (Condition 9, Condition 11, Condition 17, Condition 12, Condition 14) and 2 conditions for Subject 8 (Condition 14, Condition 20). This was a total of 12 dual task conditions across five participants. Given there were 40 dual task conditions present across all five participants, this translates to significant performance enhancement on 30% of the dual task conditions in the participant pool. By this same measure of significance (greater than one standard deviation of negative net performance percentage change), there were only three dual task conditions across all five subjects in which there were statistically significant performance detriments. This equates to only 7.5% of dual task conditions in which there were significant dual task performance detriments.

Only fifteen dual task conditions were considered as “significant” in respect to enhancement or detriment, which means there were twenty five other dual task conditions which exhibited some type of enhancement or detriment even if they did not represent “significant” changes. Of these “non-significant” changes, thirteen conditions showed enhancements and twelve showed detriments. Therefore, in total, twenty five of the dual task conditions indicated enhancements of some kind, and fifteen of the dual task conditions indicated detrimental performance of some degree. Of the forty total dual task conditions, 62.5% showed some sort of performance enhancement, and 37.5% showed some sort of performance detriment.

## V. Discussion

### A. Did Dual Task Paradigm confirm or contradict the previous findings regarding the laterality of pitch and rhythm in the brain?

The data from these four analyses are not conclusive enough to confirm or negate the presented hypotheses. Based on the presented data, it is not likely that order of condition presentation affected subject performance on the conditions. Possible reasons for the lack of strong trends in the data include the group size used for data analysis. Given the great variability across the five participants, these data likely do not reflect the dual task capacities of a typical brain. In order to have the statistical power to discern performance patterns for the typical brain, a much larger participant pool would be required. In turn, it could be advantageous to analyze the rest of the data collected, and also to administer a refined version of this experiment to a larger group of individuals. It would be necessary to carry out a power analysis to determine the number of participants required to achieve reliable data. This would help determine if further investigation using the dual task paradigm is feasible. If the power analysis indicates that two thousand participants would be required to yield reliable statistical results, then utilizing the present dual task paradigm methods would not be feasible.

Despite the inconclusive data, a noteworthy trend was present. Of the dual task conditions, 30% exhibited a statistically significant enhancement, whereas 7.5% of conditions showed a statistically significant detriment. Of all types of net performance changes (significant and non-significant), twenty five of the dual task conditions showed some type of enhancement, and fifteen of them showed some type of detriment. Percentage-wise, this indicates 62.5% enhancement in the dual task conditions, and 37.5% showed some sort of detriment. This challenges our presumption that performance detriments would be present in all or most dual

task conditions. The dual task detriment theory operates on the idea that when increased attention is required to attend to a task, it will interfere with the individual's ability to process a second simultaneous task. However, very recent literature discusses the idea of an "attentional boost" in dual task interaction. According to researchers Swallow and Jiang (2013), when one task presented to an individual represents a "target", the individual's memory and performance for a concurrently presented task will be enhanced. Instead of causing cognitive resource competition, the identification of a "target" task triggers a boost in attention which heightens attentiveness and recall abilities for the other presented task. Target recognition has a neurobiological basis, which involves a surge in activity in the locus coeruleus norepinephrine system (LC-NE system). This selection process appears to be of a temporal nature that expedites processing of the target as well as the stimuli presented simultaneously with the target. This means that if the subject is presented with a perceived target, they will experience heightened perception of the concurrent background task (the verbal tone sequence task) within a time frame of one hundred milliseconds before and after the target (checkbox task) is completed. Given the dual task required simultaneous attention to the verbal tone sequence task and the motor checkbox task, it is plausible that for many of the conditions the subjects decided that the "checkbox" was a target and as a result their recall abilities for the verbal task were enhanced relative to the single task baseline condition. The idea of the attentional boost is not that it occurs in the place of dual task interference, but rather that it occurs alongside dual task interference in the face of this specific condition of "target identification". In some cases, the performance enhancement brought about by the attentional boost can override any dual task interference which may be occurring for that task. This theory could account for why the majority of net performance changes for the dual task conditions were observed as enhancements as opposed to detriments as were hypothesized.

Another explanation for the performance enhancements is the idea of cognitive resource utilization. In single task conditions, it is possible that the subjects could not be completely focused on the task at hand because not all of their cognitive resources were being allocated towards the activity. When they were presented with a second task to complete simultaneously (such as an introduced motor task to complete alongside the verbal task), this could reduce mind-wandering and increase cognitive arousal levels so that overall performance on the dual task condition is enhanced relative to the separate single task performances (Andrade, 2009). Dual task conditions are designed to identify how two different cognitive tasks are processed, yet the dual task paradigm may not be a reliable method for assessing cerebral organization if the effects of boredom and mind-wandering possibly present in the single task condition performance are not accounted for. Andrade conducted a study in which participants were asked to listen to a mock phone call and then recall details from it immediately afterwards. The control group was instructed only to listen to the phone call, and performance was evaluated based how well they recalled information from the phone call. A second group was asked to “doodle” simultaneously, which involved shading in rows of shapes with a pencil. The doodling group had their performance assessed based on the average number of shapes they could fill in, as well as how accurate their recall of the telephone call was. Overall, participants in the “doodling” group recalled an average of 7.5 pieces of information from the phone call, which was 29% percent more than the 5.8 average pieces of information recalled by the “listening only” group. This illustrates that the involvement of the “doodling” motor activity actually facilitated information recall in the dual task condition, as opposed to causing a detriment in performance. Andrade proposed that the addition of the doodling activity harnessed more cognitive resources in the brain and therefore resulted in enhanced performance on the information recall task.

Other variables could have influenced participant performance on the conditions. These include varying sleep levels (which was not taken into account when administering the experimental conditions), unknown experimental error, or music or academic content the participant was exposed to prior to experimentation which could have primed the brain to respond in certain ways to the verbal and motor tasks. In regard the motor checkbox task, all participants were instructed to start at the same checkbox with the checkbox sheet facing a standardized direction. However, the direction and configuration that participants chose to make their checkboxes in varied from participant to participant. This could have resulted in a variety of motor movements across the checkbox sheet, which could have caused variability in the number of checkboxes each participant was able to complete.

We revisit the research question proposed earlier in the thesis: Can a Dual Task Paradigm be used to confirm or contradict previous findings regarding the laterality of pitch and rhythm? The inconclusive results of the study along with the noteworthy presence of dual task enhancements (as opposed to the anticipated detriments) indicate that this method of inquiry is not appropriate for exploring the cerebral organization of pitch and rhythm.

#### B. Implications for Aphasia Therapy

The motivation for this research project was to gain a better understanding of how the brain processes pitch and rhythm of speech. If different laterality was determined for pitch and rhythm in the neurologically normal participants, this information could be used to refine the already successful MIT technique (Helm-Estabrooks, 1989) by providing an empirical basis for emphasizing left hemisphere-controlled tasks in the administration of MIT. Embedding left hemisphere-controlled tasks into a regimen of MIT could hypothetically rehabilitate the language dominant (left) hemisphere more quickly than the original MIT treatment or other non-intoned

therapies currently used for those with aphasia. If a speech therapist aims to stimulate a patient's right cerebral hemisphere in the acute phase of stroke recovery (in attempt to encourage the right hemisphere to take on lost language function), they could utilize melodic stimuli which incorporate right hemisphere-controlled melodic tasks. This would hypothetically cause enhanced right hemisphere activation, and could result in more immediate right hemisphere recruitment for language function. Alternatively, the speech pathologist might aim to rehabilitate the left cerebral hemisphere only, which is the predominant hemisphere for language processing. They might facilitate this by embedding stimuli into therapy which features left hemisphere-controlled tasks instead. A modified version of MIT with improved effectiveness could have several positive implications for society; 1) faster functional language recovery for those with aphasia, resulting in improved post-stroke communication abilities 2) more efficient utilization of insurance and Medicaid funding for medical rehabilitation services.

Although the Dual Task Paradigm method might not be appropriate to confirm or contradict previous findings, given the credibility of those reviewed literature sources the laterality for pitch and rhythm is likely as we hypothesized. While the Dual Task Paradigm does not allow for this kind of exploration, it doesn't change these predicted laterality patterns that are likely present within the brain. Future steps could include formal imaging studies which examine the laterality of processing for pitch and rhythm features in the brain. Alternatively, a modified version of MIT could be developed that does not emphasize pitch changes, but rather metric rhythms. The goal of this refined version of therapy would be to encourage the left hemisphere to take on language function once again. This therapeutic goal is in line with research showing that the best long term language recoveries from aphasia result when language re-lateralizes to the left hemisphere. The current version of MIT entails melodically intoning phrases "Open the

door” and left hand tapping, and it also contains nonmetric rhythmicity (as regular speech is characteristically nonmetric, as the syllables are of varying durations). Imaging studies indicate that this therapy recruits the right hemisphere for language function more extensively than the left hemisphere (Schlaug et al, 2008). The proposed revised version of MIT would feature the syllables of “Open the door” with a metric rhythm (syllables all of the same duration), and the patient would use a drum to set the beat with their right hand. For many patients with aphasia this will likely involve hand and arm movement with their hemiparetic right arm, which can be done with assistance from the speech-language pathologist. The combined metric rhythmicity and right hand motion would be presumed to activate the left hemisphere much more extensively than the right hemisphere. This is given the literature-supported idea that metric rhythms are processed in the left hemisphere, and also that right hand movements are controlled by the contralateral left hemisphere. It would be hypothesized that the combined metric rhythmicity and the right hand tapping of the revised MIT would cause greater language improvement in patients than for those treated with the traditional MIT.

To determine the relative efficacy of the refined MIT regimen compared to the traditional MIT, an imaging study could be done which compares the cerebral activation patterns and correspondent language outcomes for both therapies. This would entail comparing imaging scans and language progress of traditionally-delivered MIT at 1 month, 3 months, and 9 months post-incident. This ongoing monitoring of cerebral activity would be necessary since any differential effects of the two therapies might not be evident at only 1 month post-incident.

Another potential implication for the administration of MIT is the likely occurrence of performance enhancement in dual task condition pairings. The doodling exercise in Andrade’s study was very similar to the motor checkbox activity in our present study. The information in



the phone call was presented to Andrade's participants auditorily, as were the tonal sequences to participants in our present study. MIT is, essentially, a dual task setup. Like Andrade's study and our present study, MIT features a motor task (hand-tapping) as well as auditorily presented stimuli that the individual must repeat (functional phrases that the patient repeats with pitch fluctuations). Therefore it is feasible that dual task facilitation could also be occurring for patients who are given MIT. The analogous constructs between Andrade's study, the present study, and MIT, challenge the notion that the documented MIT-induced language improvements are only attributable to the recruitment of the non-damaged right hemisphere. This suggests that MIT's success in increasing patient language output could also be due in part to the presence of dual task "attentional boost" and cognitive resource harnessing that occur in the aforementioned studies involving dual task setups.

## VI. Conclusion

Inconclusive data and unanticipated enhancement trends indicate that the Dual Task Paradigm is not an appropriate method for exploring the cerebral laterality of pitch and rhythm. Despite this fact that the data did not confirm or negate the proposed hypotheses, the cerebral laterality of pitch and rhythm are still likely as hypothesized. With the goal of re-lateralizing language function to the left hemisphere for optimum recovery, a modified version of MIT should be developed that features metrically rhythmic syllables and right hand tapping (as opposed to the melodic intonations and left hand tapping of traditional MIT). This modified version should then be implemented alongside traditional MIT, in order to determine if embedding metrically rhythmic stimuli and right hand tapping do in fact facilitate relatively faster recovery from aphasia compared to regular MIT. Also, given that the majority of dual task conditions showed performance enhancements instead of detriments, this suggests the

involvement of dual task facilitation. This suggests that MIT's relative success in facilitating recovery from aphasia is attributed not only to the right hemisphere recruitment mechanism, but also to the dual task facilitation which can occur when the two tasks are being performed simultaneously.

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---- **CU Boulder Speech, Language and Hearing Sciences Department** ----

## **Aphasia Research Lab**

# **Are You Interested in Participating in a Research Study About the Brain?**

Are you 18 years of age or older?

Are you a monolingual speaker of American English?

Are you right-handed?

Are you without a history of neurological injury/disease, learning disability, speech-language or hearing impairment?

Do you have no formal musical training?

Do you have full use of both hands and arms?

**If you fit these criteria, we want you!**

**WHAT YOU'LL BE ASKED TO DO IF YOU PARTICIPATE:** You'll be asked to participate in a preliminary phone call screening, and two one-hour testing sessions at the Speech, Language and Hearing Sciences building on the CU-Boulder Campus. Tests will involve listening and reproducing sounds, and doing a motor task with your hands.

**COMPENSATION:** You will be paid \$20 for full study participation.

**If interested in learning more, send your name and phone number to: [aphasialab@colorado.edu](mailto:aphasialab@colorado.edu)**



*Buff Bulletin and SLHS student email announcement*

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## Appendix B

### Condition Types

Condition Type 1: Met, NPC-Metric, No Pitch Change Tone Sequence

Condition Type 2: Met, PPC-Metric, Predictable Pitch Change Tone Sequence

Condition Type 3: Met, RPC-Metric, Random Pitch Change Tone Sequence

Condition Type 4: NMet, NPC-Nonmetric, No Pitch Change Tone Sequence

Condition Type 5: NMet, PPC-Nonmetric, Predictable Pitch Change Tone Sequence

Condition Type 6: NMet, RPC-Nonmetric, Random Pitch Change Tone Sequence

### Conditions

#### *Single Task Conditions*

1-Metric, No Pitch Change

2-Metric, Predictable Pitch Change

3-Metric, Random Pitch Change

4-Nonmetric, No Pitch Change

5-Nonmetric, Predictable Pitch Change

6-Nonmetric, Random Pitch Change

7-Right Hand Motor Task

8-Left Hand Motor Task

#### *Dual Task Conditions*

9-Right Hand + Metric, No Pitch Change

10-Right Hand + Metric, Predictable Pitch Change

11-Right Hand + Metric, Random Pitch Change

12-Right Hand + Nonmetric, No Pitch Change

13-Right Hand + Nonmetric, Predictable Pitch Change

14-Right Hand + Nonmetric, Random Pitch Change

15-Left Hand + Metric, No Pitch Change

16-Left Hand + Metric, Predictable Pitch Change

17-Left Hand + Metric, Random Pitch Change

18-Left Hand + Nonmetric, No Pitch Change

19-Left Hand + Nonmetric, Predictable Pitch Change

20-Left Hand + Nonmetric, Random Pitch Change